LUTROS, LLC

Bridgeport Biodiesel Emissions Estimate Amendment

Prepared for

BRIDGEPORT BIODIESEL 1 & 2

by

LUTROS, LLC

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Submitted by:

Travis Danner
Vice President Engineering
LUTROS, LLC
721 Scenic Highway
Lookout Mountain, TN 37350
Phone: 423.702.4414
Fax: 423.702.4413
Mobile: 770.655.6736
E-mail: travis@lutros.com
www.lutros.com

This document was prepared to address specific follow-up questions raised by CT DEEP in regards to previously submitted reports containing estimates for Bridgeport Biodiesel 1 (BBD1) and Bridgeport Biodiesel 2 (BBD2). These follow-up questions as requested by Alyssa Park are numbered and listed below; answers to each question immediately follow the question.

1. **On your mass balance reports submitted to the MMCA Bureau, what methods are you using to measure inventory?**

Inventory in BBD1 is measured in gallons by factory markings on the tanks. Accuracy of this method is approximately ±25 gallons.

Inventory in BBD2 will be measured by level sensors: Siemens LU 12m level sensors. These sensors have a rated accuracy of 0.25".

2. **What methods are you using to quantify the incoming and outgoing products? Do you have flowmeters for incoming/outgoing streams? What are the accuracies of these methods?**

Incoming and outgoing products for both BBD1 and BBD2 are quantified via truck scale. Typical commercial truck scales have an accuracy of ±20lbs. This would represent an accuracy of ±0.025% on a fully load truck.

Coriolis flowmeters are also used to quantify streams into and out of the biodiesel production process. These flowmeters have an accuracy of ±0.1%.

3. **I need more information pertaining to the potential methanol emission calculations for the process emissions. Lutros included detailed calculations for potential methanol emissions due to storage and fugitive losses, but I was unable to find any for the process emissions. I performed my own calculations and am not coming up with the same amounts as Lutros did in their reports. I would like to see detailed calculations for the following:**
    a. **the transesterification reactor and wash process tanks for BB #1 and**
    b. **vacuum system exhaust, process tanks cycling, and methanol distillation cycling for BB#2. Please include all assumptions made and the basis for the assumptions in the calculations. For example, why was it assumed that the process tanks are cycled once per month and the distillation column each week?**

BBD1 Transesterification Reactor

The transesterification reactor employed by BBD1 is a 634 gallon reactor which is filled with 628 gallons of reactants per batch. 2.76 hours is the minimum time required to fill, react, and empty the reactor. With a 2.76 hour cycle time, there is the potential for 3,176 batches per year which results in the potential to vent 10.1 tons of air per year The vapor pressure and corresponding partial pressure of methanol at the average vent conditions (70F, 0 psig) was calculated to estimate the methanol entrained in these 10.1 tons of air; **the potential to emit methanol due to reactor cycling is 1.74 tons/yr**. Table 1 below shows the calculations for BBD1 transesterification reactor. Pertinent assumptions are listed in the table.

TABLE 1: BBD1 Transesterification Reactor Calculations

Batch Cycle Time	2.76	hrs
Batches per Year	3174	
Exhaust Temperature	294	K
Exhaust Temperature	70	F ←
Vacuum Pressure	14.696	psia
Condensing Pressure	14.696	psia
Air Density	0.076	lbm/ft3
Condenser Air Density	0.076	lbm/ft3
Air Entrainment	628	Gallons
Air Entrainment	6.381	lbm
Vapor Pressure MeOH	1.9708	psia
→ Molar fraction MeOH	0.1341	
Mass fraction MeOH	0.1464	
Mass flowrate MeOH	1.09	lb emit per reaction
Annual Emission	3473	lbm/yr
	1.736	tons/yr

BBD1 Wash Process Tanks

From the transesterification reactor reactants are cooled and pumped to one of three 6,000 wash tanks wherein byproduct glycerin is settled and contaminates including methanol are water-washed from the biodiesel. Eight reactor batches enter one wash tank before it is locked out and reactor batches are diverted to one of the other two wash tanks. With eight reactor batches per wash batch there is the potential for 397 wash batches per year distributed among the three wash tanks each containing 5,040 gallons of reacted products. This results in the potential to emit a combined 10.1 tons of air as these tanks are filled. The vapor pressure and corresponding partial pressure of methanol at the average vent conditions (95F, 0 psig) was calculated to estimate the methanol entrained in these 10.1 tons of air; **the potential to emit methanol due to wash tank cycling is 4.24 tons/yr**. Table 2 below shows the calculations for BBD1 wash tanks. Pertinent assumptions are listed in the table.

Note that the reactor and wash tanks are vented through a control device—a chilled condenser followed by a scrubber. The condenser is maintained at 60F and alone reduces the combined emissions from the process tanks from a potential of 5.97 tons/yr to a potential of 2.08 tons/yr.

TABLE 2: BBD1 Wash Tanks Calculations

Batch Cycle Time	22.08	hrs
Batches per Year	397	
Exhaust Temperature	308	K
Exhaust Temperature	95	F
Vacuum Pressure	14.696	psia
Condensing Pressure	14.696	psia
Air Density	0.076	lbm/ft3
Condenser Air Density	0.076	lbm/ft3
Air Entrainment	5040	Gallons
Air Entrainment	51.209	lbm
Vapor Pressure MeOH	4.0182	psia
Molar fraction MeOH	0.2734	
Mass fraction MeOH	0.2941	
Mass flowrate MeOH	21.34	lb emit per wash
Annual Emission	8466	lbm/yr
	4.233	tons/yr

BBD2 Process Tanks Cycling
Under steady-state conditions there is no potential to emit (apart from fugitive emissions) from the process tanks. Upon filling the process tanks air in the tanks is pushed through the vacuum system and exhausted. The first step to quantifying the potential to emit methanol is to estimate the mass of air pushed through the vacuum system due to process tank cycling each year. The total volume of all process tanks is approximately 20,000 gallons, and if it is assumed that the process tanks are cycled once per month, cycling process tanks will contribute 1.22 tons/yr of air passing through the vacuum system. The vapor pressure and corresponding partial pressure of methanol at the exit conditions (45F, 0 psig) was calculated to estimate the methanol entrained in these 1.22 tons of air, **the potential to emit methanol due to process tank cycling is 0.09 tons/yr.**

Table 3 below shows the calculations for BBD2 process tanks. Pertinent assumptions are listed in the table. Note that process tanks will not typically be emptied upon system shut down. Process tanks need only be emptied as needed to perform maintenance and repairs. For these calculations it was assumed process tanks would be emptied once per month for maintenance and repairs, although, in actuality it is expected to be much less frequent than that.

TABLE 3: BBD2 Process Tanks Calculations

Start Ups per Year	12	
Chiller Temperature	280.22	K
Chiller Temperature	45	F
Vacuum Pressure	14.696	psia
Condensing Pressure	14.696	psia
Air Density	0.076	lbm/ft3
Condndesing Air Density	0.076	lbm/ft3
Air Entrainment	20000.00	Gallons
Air Entrainment	203.209	lbm
Vapor Pressure MeOH	0.8902	psia
Molar fraction MeOH	0.0606	
Mass fraction MeOH	0.0666	
Mass flowrate MeOH	14.51	lbs per start up
Annual Emission	174	lbm/yr
	0.087	tons/yr

BBD2 Methanol Distillation Cycling
Cycling the distillation column is of the exact same nature as cycling the process tanks above. The distillation column will be operated under slight vacuum—13.7 psia. Consequently, Any air exhausted from the system will exit through the vacuum system. The total volume of the distillation column is approximately 1,000 gallons, and if it is assumed the distillation column is cycled 52 times per year, the cycling of the distillation column will result in 0.26 tons of air exiting through its condenser. The vapor pressure and corresponding partial pressure of methanol at the exit conditions (60F, 0 psig) was calculated to estimate the methanol entrained in these 0.26 tons of air, **the potential to emit methanol due to distillation column cycling is 0.02 tons/yr**. Note the methanol distillation column condenser is also treated as a process condenser as it is both inline with a vacuum source and the methanol condensate is being recovered for reuse.

Table 4 below shows the calculations for BBD2 methanol distillation cycling. Pertinent assumptions are listed in the table. Note that unlike process tanks when the distillation column is shut down it will by nature evacuate itself of its process fluid. That is, under normal operation the distillation column is full of hot vapors. When shutdown these vapors will condense pulling a vacuum on the distillation column, and while the column can and will be sealed upon shut down small leaks will still permit air to leak into the system over the course of several days. Also note that the distillation column can process wet methanol at a higher rate than the system produces it. Consequently, the distillation column will not need to run at all times. It was assumed the distillation column would be operated 24 hrs/day once per week until all accumulated wet methanol was processed then shut down until the following week.

TABLE 4: BBD2 Methanol Distillation Calculations

Start Ups per Year	52	
Chiller Temperature	280.22	K
Chiller Temperature	45	F
Vacuum Pressure	14.696	psia
Condensing Pressure	14.696	psia
Air Density	0.076	lbm/ft3
Condndesing Air Density	0.076	lbm/ft3
Air Entrainment	1000.00	Gallons
Air Entrainment	10.160	lbm
Vapor Pressure MeOH	0.8902	psia
Molar fraction MeOH	0.0606	
Mass fraction MeOH	0.0666	
Mass flowrate MeOH	0.73	lbs per start up
Annual Emission	38	lbm/yr
	0.019	tons/yr

BBD2 Methanol Distillation Cycling

Cycling the distillation column is of the exact same nature as cycling the process tanks above. The distillation column will be operated under slight vacuum—13.7 psia. Consequently, Any air exhausted from the system will exit through the vacuum system. The total volume of the distillation column is approximately 1,000 gallons, and if it is assumed the distillation column is cycled 52 times per year, the cycling of the distillation column will result in 0.26 tons of air exiting through its condenser. The vapor pressure and corresponding partial pressure of methanol at the exit conditions (60F, 0 psig) was calculated to estimate the methanol entrained in these 0.26 tons of air, **the potential to emit methanol due to distillation column cycling is 0.02 tons/yr**. Note the methanol distillation column condenser is also treated as a process condenser as it is both inline with a vacuum source and the methanol condensate is being recovered for reuse.

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TABLE 4: BBD2 Methanol Distillation Calculations

Start Ups per Year	52	
Chiller Temperature	280.22	K
Chiller Temperature	45	F
Vacuum Pressure	14.696	psia
Condensing Pressure	14.696	psia
Air Density	0.076	lbm/ft3
Condndesing Air Density	0.076	lbm/ft3
Air Entrainment	1000.00	Gallons
Air Entrainment	10.160	lbm
Vapor Pressure MeOH	0.8902	psia
Molar fraction MeOH	0.0606	
Mass fraction MeOH	0.0666	
Mass flowrate MeOH	0.73	lbs per start up
Annual Emission	38	lbm/yr
	0.019	tons/yr

BBD2 Vacuum System Exhaust

Fugitive emissions in the form of air leaking into the solvent recovery system will impact the performance of the solvent recovery system—both vacuum pump performance and condenser performance. The core of *Bridgeport Biodiesel 2's* solvent recovery system consists of two integral process condensers followed by two vacuum pumps in series—Appendix D provides process flow diagrams for the biodiesel production process and supporting systems. The first vacuum pump is a liquid ring vacuum booster pump and the second a liquid driven eductor. The condensers are treated as process condensers according to the MON NESHAP rule (Subpart FFFF—NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS: MISCELLANEOUS ORGANIC CHEMICAL MANUFACTURING), "process condenser" is defined in §63.2550 as follows:

> *Process condenser* means a condenser whose primary purpose is to recover material as an integral part of an MCPU. All condensers recovering condensate from an MCPU at or above the boiling point or all condensers in line prior to a vacuum source are considered process condensers. Typically, a primary condenser or condensers in series are considered to be integral to the MCPU if they are capable of and normally used for the purpose of recovering chemicals for fuel value (i.e., net positive heating value), use, reuse or for sale for fuel value, use, or reuse. This definition does not apply to a condenser that is used to remove materials that would hinder performance of a downstream recovery device as follows:
> (1) To remove water vapor that would cause icing in a downstream condenser, or
> (2) To remove water vapor that would negatively affect the adsorption capacity of carbon in a downstream carbon adsorber, or
> (3) To remove high molecular weight organic compounds or other organic compounds that would be difficult to remove during regeneration of a downstream carbon adsorber.

The condensers employed by *Bridgeport Bridgeport 2* for solvent recovery:

1. recover condensate in line prior to a vacuum source, and
2. are capable and normally used for the purpose of recovering methanol for reuse.

Additionally, vacuum system could neither technically nor economically operate without the condensers. The condensate recovery rate from these condensers will be 2.5 gallons/minute; at the design vacuum depth of 28.5 inHg this represents over 4500 ACFM. The vacuum pumps will accommodate no more than 250 ACFM at the design vacuum depth. Consequently, the vacuum system could not feasibly maintain the required depth of vacuum in the absence of the process condenser. Furthermore, 2.5 gpm of methanol at $1.90/gal represents over $1.8MM/yr such that it is not economically viable to operate the system in the absence of this condenser. Thus, this condenser is treated as an integral process condenser. It is not considered a control device.

The only steady-state potential to emit from the process is the result of fugitive air emissions into the vacuum solvent recovery system reducing the partial pressure of the methanol vapor enabling it to pass through the process condenser and vacuum pumps. These fugitive emissions of air into the vacuum system have been estimated using the Average Emission Factor Approach as outlined in

Section 2.3.1 of the 1995 Protocol for Equipment Leak Emission Estimates. Once the extent of air entrainment was determined the potential to emit methanol in the vacuum exhaust was calculated based on the vapor pressure of methanol at the temperature (45F) of the vacuum eductor loop and the corresponding partial pressure of methanol in the exiting exhaust stream. **Note the potential to emit methanol in the vacuum system exhaust stream is 0.58 tons/yr.**

Table 5 below shows the calculations for BBD2 vacuum system exhaust. Pertinent assumptions are listed in the table. Appendix C provides detailed calculations for air leaking into the vacuum system and shows an estimated 8.06 tons/yr of air entering the vacuum system. This corresponds to an air entrainment of 1.84 lb/hr used in Table 5 to estimate potential to emit methanol due these air leaks into the vacuum system.

TABLE 5: BBD2 Vacuum System Exhaust Calculations

Chiller Temperature	280.22	K
Eductor Loop Exit Temperature	45	F
Vacuum Pressure	14.696	psia
Condensing Pressure	14.696	psia
Air Density	0.076	lbm/ft3
Condensing Air Density	0.076	lbm/ft3
Air Entrainment	0.40	ACFM
Air Entrainment	1.840	lbm/hr
Vapor Pressure MeOH	0.8902	psia
Molar fraction MeOH	0.0606	
Mass fraction MeOH	0.0666	
Mass flowrate MeOH	0.13	lbm/hr
Annual Emission	1151	lbm/yr
	0.576	tons/yr